"Changing the Economics of Underground Parking Structures"

Members of the parking industry are no stranger to the costs associated with both above and below grade parking structures. Historically, underground parking garages are anywhere from 1.5 to 2 times the costs of above ground parking decks. The inherent benefits of underground parking are too often overshadowed by the costs of foundation construction. Below grade methods have additional structural design issues such as groundwater, deep cut excavation and shoring that above grade does not.

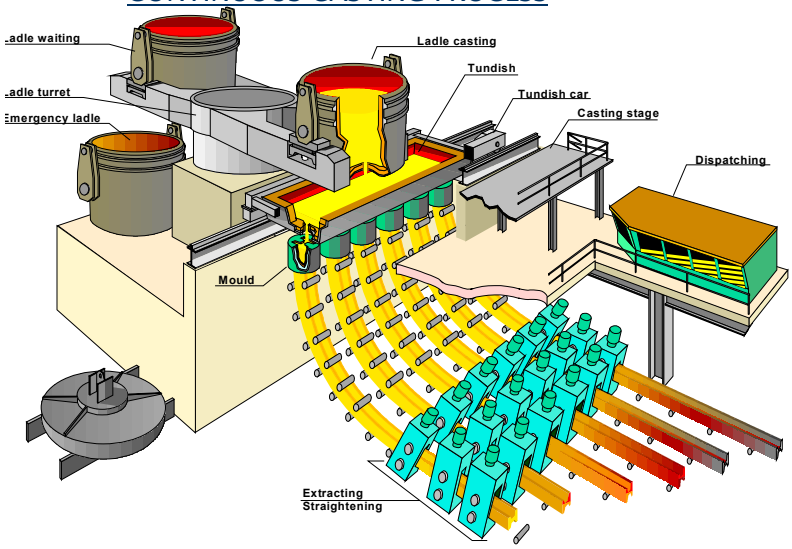
An innovative design concept utilizing sheet piling as the permanent basement wall is changing the economics of parking garage construction. Although virtually new to the US, this technology has been in practice throughout Europe for more than 20 years. So much so that European designers consider sheet piling ahead of alternative concrete methods when evaluating design feasibility.

So why has this not caught on in the US? It starts with "perception". Owner, consultant and contractor alike generally view sheet piling as a unattractive shoring material mostly used for marine applications. Furthermore, general site construction perceives sheet piling as a temporary works material. The concept of incorporating the structural attributes of sheet piling into the permanent building design is just not common practice. Skyline Steel is a steel foundation company specializing in innovative design solutions working to change the historical mindset and misperceptions to bring this technology to the Parking Industry.

Sheet Piling 101

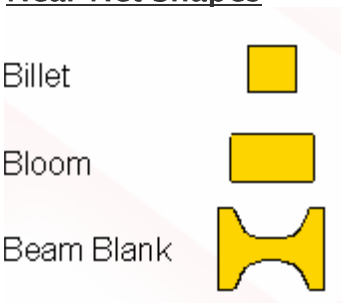
For those of you not familiar with the product, hot rolled steel sheet piling is manufactured by less then 10 producers throughout the world. There are numerous shapes and systems for a multitude of structural applications.

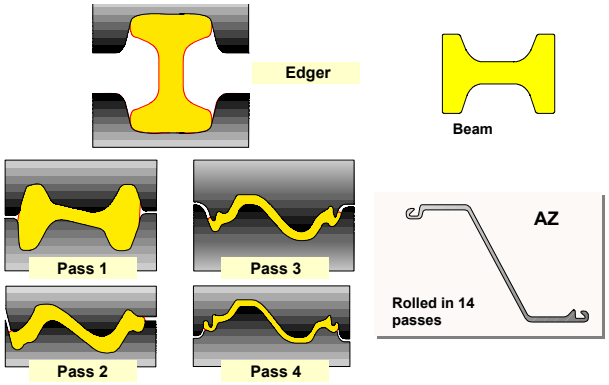
CONTINUOUS CASTING PROCESS

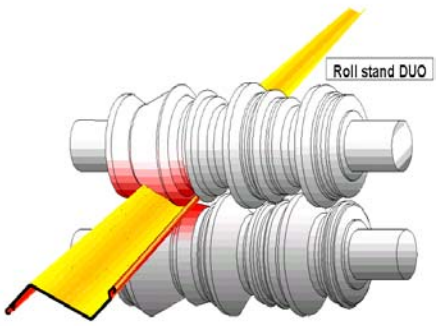


Because the US is predominantly a Z-Pile market, we will focus on the Z shaped sections. Z-Piles are produced from a continuous casting steel process from some of the same mills that produce standard structural shapes for bridge and building erection. This "mini-mill" technology streamlines steel production so that all products can be hot rolled from 3 continuously cast near net shapes. Z-Piles are produced from the beam blank. Once cast, it moves through a series of stands in the rolling mill making 3 or 4 passes at each. Each pass shapes the beam blank closer to the finished shape. The intricate interlock design and differential thicknesses make this the most difficult structural shape to produce.

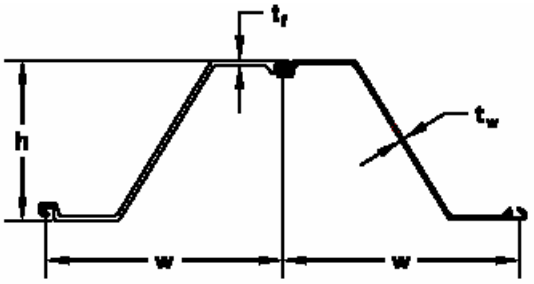
Near Net Shapes







The structural properties such as Section Modulus and Moment of Inertia refer to a sections ability to resist forces under loading. This method of analysis is referred to as simple beam theory, which is standard for beam and column design.



AZ Hot Rolled Steel Sheet Piling

SECTION	Width (w) in (mm)	Height (h) in (mm)	THICKNESS Flange (t_f) in (mm)	THICKNESS Web (t_w) in (mm)	WEIGHT Pile lb/ft (kg/m)	WEIGHT Wall lb/ft² (kg/m²)	Section Modulus in³/ft (cm³/m)	Moment of Inertia in⁴/ft (cm⁴/m)	COATING AREA Both Sides ft²/ft of single (m²/m)	COATING AREA Wall Surface ft²/ft² (m²/m²)
AZ 12	26.38 *670*	11.89 *302.0*	0.335 *8.50*	0.335 *8.50*	44.42 *66.10*	20.22 *98.70*	22.3 *1200*	132.8 *18140*	5.45 *1.66*	1.23 *1.23*
AZ 13	26.38 *670*	11.93 *303.0*	0.375 *9.50*	0.375 *9.50*	48.38 *72.00*	22.02 *107.5*	24.2 *1300*	144.3 *19700*	5.45 *1.66*	1.23 *1.23*
AZ 14	26.38 *670*	11.97 *304.0*	0.413 *10.50*	0.413 *10.50*	52.62 *78.30*	23.94 *116.90*	26.0 *1400*	156.0 *21300*	5.45 *1.66*	1.23 *1.23*
AZ 17	24.80 *630*	14.92 *379.0*	0.335 *8.50*	0.335 *8.50*	45.96 *68.40*	22.24 *108.60*	31.0 *1665*	231.3 *31580*	5.64 *1.72*	1.35 *1.35*
AZ 18	24.80 *630*	14.96 *380.0*	0.375 *9.50*	0.375 *9.50*	49.99 *74.40*	24.19 *118.10*	33.5 *1800*	250.4 *34200*	5.64 *1.72*	1.35 *1.35*
AZ 19	24.80 *630*	15.00 *381.0*	0.413 *10.50*	0.413 *10.50*	54.43 *81.00*	26.34 *128.60*	36.1 *1940*	270.8 *36980*	5.64 *1.72*	1.35 *1.35*
AZ 25	24.80 *630*	16.77 *426.0*	0.472 *12.00*	0.441 *11.20*	61.49 *91.50*	29.74 *145.20*	45.7 *2455*	382.6 *52250*	5.91 *1.80*	1.41 *1.41*
AZ 26	24.80 *630*	16.81 *427.0*	0.512 *13.00*	0.480 *12.20*	65.72 *97.80*	31.79 *155.20*	48.4 *2600*	406.5 *55510*	5.91 *1.80*	1.41 *1.41*
AZ 28	24.80 *630*	16.85 *428.0*	0.551 *14.00*	0.520 *13.20*	70.15 *104.40*	33.94 *165.70*	51.2 *2755*	431.6 *58940*	5.91 *1.80*	1.41 *1.41*
AZ 34	24.80 *630*	18.07 *459.0*	0.669 *17.00*	0.512 *13.00*	77.61 *115.50*	37.54 *183.30*	63.8 *3430*	576.3 *78700*	6.10 *1.86*	1.47 *1.47*
AZ 36	24.80 *630*	18.11 *460.0*	0.709 *18.00*	0.551 *14.00*	82.11 *122.20*	39.73 *194.00*	67.0 *3600*	606.3 *82800*	6.10 *1.86*	1.47 *1.47*
AZ 38	24.80 *630*	18.15 *461.0*	0.748 *19.00*	0.591 *15.00*	86.75 *129.10*	41.97 *204.90*	70.3 *3780*	637.7 *87080*	6.10 *1.86*	1.47 *1.47*
AZ 46	22.83 *580*	18.94 *481.0*	0.709 *18.00*	0.551 *14.00*	89.10 *132.60*	46.82 *228.60*	85.5 *4595*	808.8 *110450*	6.23 *1.90*	1.63 *1.63*
AZ 48	22.83 *580*	18.98 *482.0*	0.748 *19.00*	0.591 *15.00*	93.81 *139.60*	49.28 *240.60*	89.3 *4800*	847.1 *115670*	6.23 *1.90*	1.63 *1.63*
AZ 50	22.83 *580*	19.02 *483.0*	0.787 *20.00*	0.630 *16.00*	98.58 *146.70*	51.80 *252.90*	93.3 *5015*	886.5 *121060*	6.23 *1.90*	1.63 *1.63*

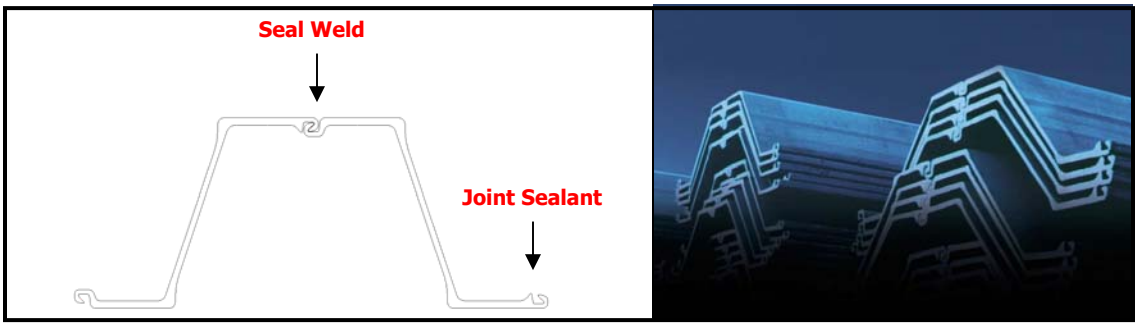
ARCELOR INTERNATIONAL AMERICA
Arcelor Group

Sheet piles are widely known for the ability to resist lateral/bending forces, yet they are also very effective in an axial/vertical capacity. This allows the structural engineer to transfer load to the perimeter walls which can reduce the number of interior support columns thereby optimizing the useable area.

Bottom Up Construction

Cast-in-place concrete basement structures require temporary shoring systems such as beam & lagging or diaphragm walls. These methods require bracing, dewatering and waterproofing all before the general construction can proceed. Such specialty contracting levels are significant cost factors in addition to the concrete foundation construction. The Arcelor Sheet Pile System for bottom up construction also requires bracing and dewatering, but eliminates the waterproofing and reinforced concrete elements.

An impervious wall system is delivered to the site in pairs with a full seal weld on the paired joint and a hydrophilic joint sealant in the female interlock. With wall thicknesses ranging from 3/8" to ¾", the owner can maximize area with the building footprint right up to the property line.



Once a few feet of soils are excavated, temporary anchorage or bracing is installed to support the sheeting from lateral earth and water pressures. Excavation and dewatering continue until the final elevation is achieved. Bearing piles are driven at the base to support the structure. The base slab is cast in place on top of the piles and work is ready to proceed upwards.

The lateral loads are transferred from the temporary anchorage or bracing to the floor slabs as each level is cast. The sheet piles are then pressure cleaned, primed and painted to an aesthetic finish. An intumescent fire coating may also be applied if needed. Incorporating the sheets into the permanent structural design results in time and material savings.

Corporate Facility: Mercedes Corporation, Germany

CONSTRUCTION SCHEDULE

CONCRETE BASEMENT WALL, COLUMN, & FOUNDATIO

Item	Description	Unit Time	Time (Hrs)
1	Temp. Sheeting	0.48/ft X 50	24
2	Columns – forms, rebar & concrete	0.114 X 450 20 X 1 0.8 X 9.5	103
3	Column Footing – forms, rebar & Concrete	0.08 X 250 13.3 X 0.55 0.6 X 34.5	48
4	Walls – forms, rebar & concrete	0.2 X 2400 25 X 1.85 1 X66.5	593
5	Wall Footing –forms, rebar & concrete	0.08 X 50 13.3 X 0.08 0.6 X 3.5	7
6	Spandrel Girder – forms, rebar & concrete	0.1 X 800 13 X 1.7 0.87 X 22	121
	SUB TOTAL		896
	7 days curing		56
	TOTAL	*(50' wall length)*	952

Analysis performed by Lichtenstein Engineering of Paramus, NJ: an independent consultant firm

This cost analysis demonstrates the time scale of a traditional reinforced concrete basement wall constructed by bottom up method. One crucial aspect of the bottom up method is that erection of the superstructure cannot proceed until the basement work is complete. This is the critical path of the project and directly influences the project schedule.

STEEL SHEET PILE & CONCRETE PIER CAP

Item	Description	Unit Time	Time(Hrs)
1	Permanent Sheeting	0.32/ft X 30	16
2	Perimeter corbel – forms, rebar & concrete	0.15 X 235 17 X 0.56 1 X 2.5	47
3	Pile Cap – forms, rebar & concrete	0.01 X 725 13 X 1.5 0.87 X 28	116
4	Spandrel Girder – forms, rebar & concrete	0.1 X 550 13 X 1.12 0.87 X 18.5	86
	TOTAL	*(50' wall length)*	265

Sheet Pile Savings: *72% Reduced Time*

As evident by the results, there is over 70% reduction in time with the steel sheet pile system compared to concrete. For example: If you were to consider a concrete foundation construction schedule of 6 months, that same project could be completed in less than 2 with sheet piling.

MATERIALS of CONSTRUCTION

CONCRETE BASEMENT WALL, COLUMN, & FOUNDATION

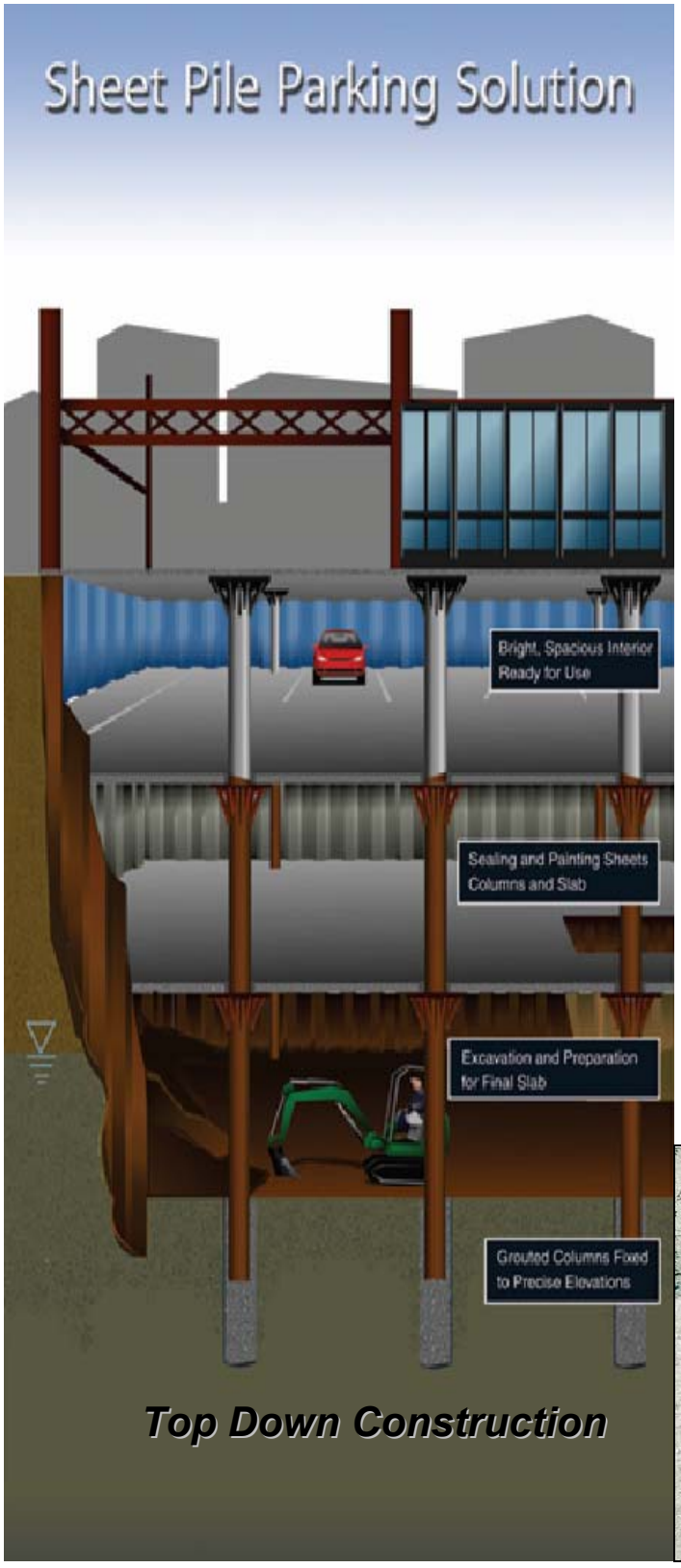
Item	Description	Unit Cost	Cost/lfw
1	Temporary Sheeting	$36.00	$1,440
2	Columns	$680.00	$136
3	Column Footing	$250.00	$175
4	Walls	$350.00	$466
5	Wall Footing	$200.00	$14
6	Spandrel Girder	$775.00	$332
	TOTAL	*(50' wall length)*	$2,563

STEEL SHEET PILE & CONCRETE PIER CAP

Item	Description	Unit Cost	Cost/lfw
1	Permanent Sheeting	$29.00	1,363
2	Perimeter Corbel	$180.00	$9
3	Pile Cap	$180.00	$101
4	Spandrel Girder	$755.00	$279
	TOTAL	*(50' wall length)*	$1,752

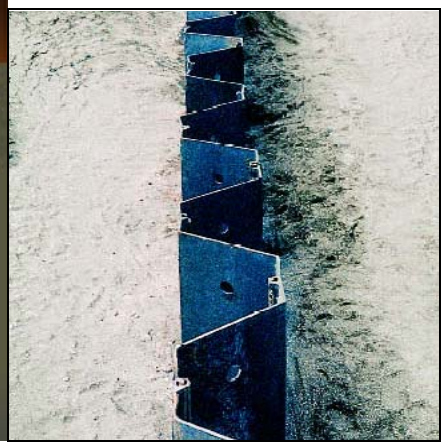
Sheet Pile Savings: *32% Material Costs*

Materials are another significant cost factor. This comparison shows the unit costs of both applications. Once again, the sheet pile system offers substantial cost savings over concrete. In total, a 72% reduction in schedule coupled with a 32% material savings dramatically reduces the unit cost/parking space. Let's not forget the 120 days of operating revenue realized from the advanced schedule. These are benefits that deserve a hard look.



Top /down Construction

Permanent steel sheet piling for top/down construction is the fastest method for total project completion. Similar in many ways to bottom up, top down offers the same benefits, and more. Think of it as bottom up on steroids. Unlike any other, this method enables construction of the superstructure concurrently with the foundation works, effectively removing it from the critical path of the project. This radically changes the project economics from a construction perspective as well as the cost of ownership.



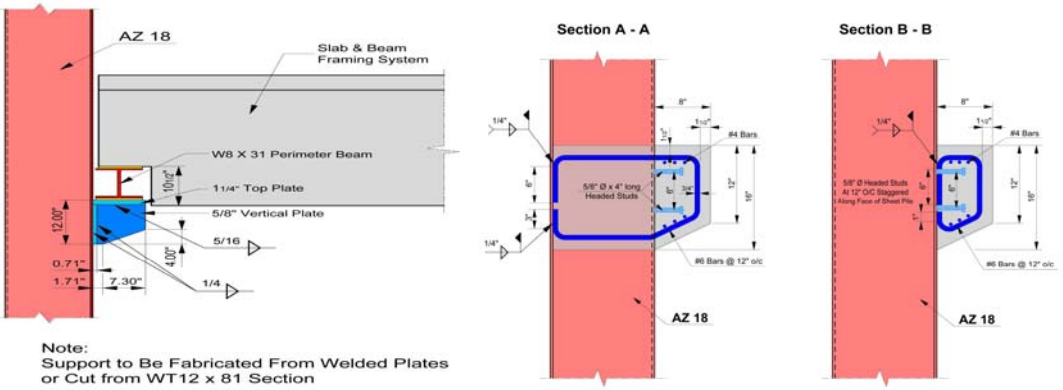
As in bottom up, the Arcelor Sheet Pile system arrives to the site in welded pairs with joint sealant. This turnkey package eliminates expensive on site fabrication and handling, enabling the contractor to focus on a fast, quality installation. The sheets are driven with a template to insure accuracy.

Once the perimeter sheet pile box is complete, the pre-fabricated internal column piles (or another system) are placed inside the augered casing. The piles are set to precise elevations and anchored at the base with concrete. The temporary casing is extracted for reuse and additional material cost savings. The site is graded for preparation of the ground floor construction. A polythene sheeting is

Sheeting is laid and a 3" slurry mud mat is poured to create a level under finish to the reinforced concrete slab. You may be wondering how the lower level excavation will take place if the ground floor is cast! Access holes are designed to allow for light & air entrainment during removal of spoils. The polythene sheeting and mud mat are chipped away during the lower excavation, exposing the finished underside of the floor.

With the ground floor and column piles set, our basement works are proceeding below. Although this method of excavation in a confined area is slower than an open pit site, the overall benefits easily absorb the additional cost. The foundation is in tact

and ready for load bearing service, allowing erection crews to commence above grade construction simultaneously. In addition to the lateral forces of the excavation, the sheets are capable of carrying perimeter axial loads from the growing structure above. As columns and sheets are exposed, the area is graded and prepared for placement of the lower level slab. A structural connection between the slab and sheets is designed to support the slab about the perimeter. A variety of connections are available for both cast in place and precast floors.



As the lower levels are completed, a seal weld is applied to the interior side of the threaded interlock. This weld is non structural and relatively inexpensive. Although the interlocks have sealant, this is an added measure to assure waterproofing.

Once completed, this innovative use of sheet piling provides an aesthetically pleasing structure at reduced costs without compromising quality. With these two methods of construction, the versatility of sheet piling could possibly change the way underground parking structures are designed and built in the US.

"Shift your next project into gear with Skyline Steel"

Skyline Steel has a team of sheet pile design experts that offer free assistance to you or your consultant in evaluating your next parking garage project. To learn more about this technology, please visit our website at www.skylinesteel.com. Or contact us @ 800 376-2096.

Dean Abbondanza
Manager, Market Development
Skyline Steel LLC, ***Arcelor Projects***